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(58) Field of search **F1T**

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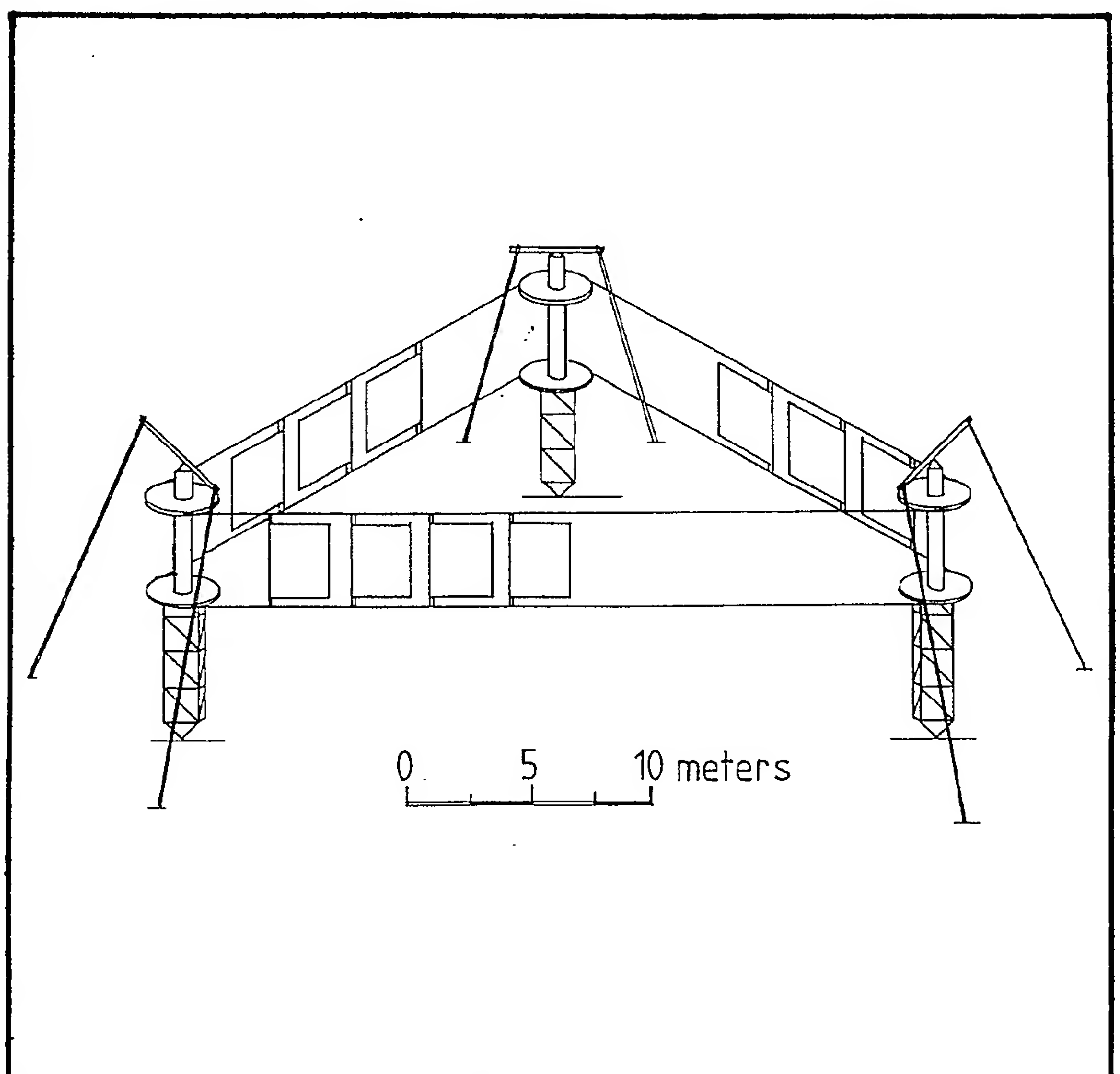
(54) Device for extracting energy from wind or water

(57) The device consists of a series of flexible sails mounted on one or more endless belts running around two or more fixed pivot points placed some distance apart and providing the sole support for the belts. Power can be extracted from either the motion of the belts, or the rotary motion at one or more of the pivot points.



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The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.
The claims were filed later than the filing date within the period prescribed by Rule 25(1) of the Patents Rules 1982.

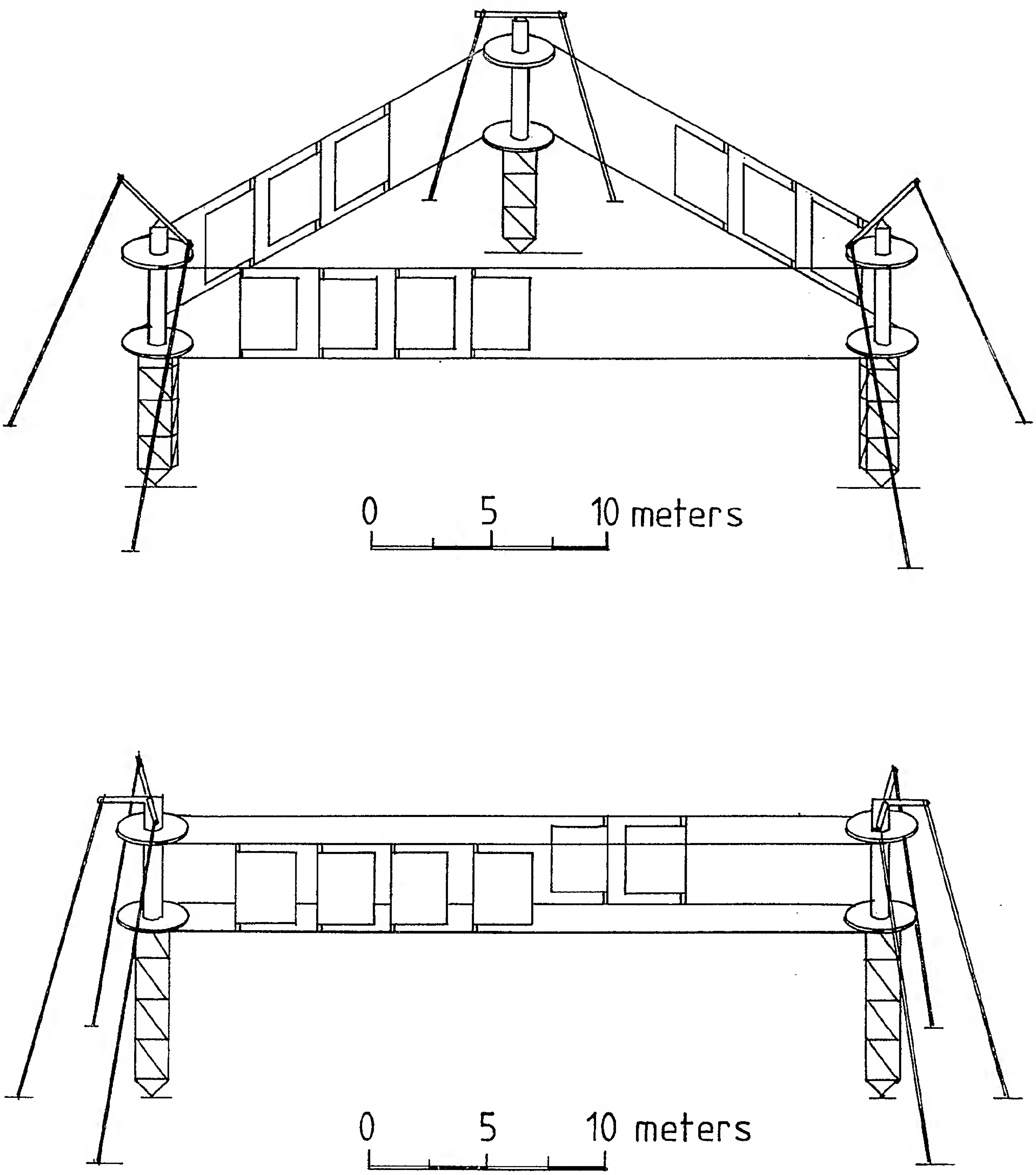


fig 1a

Note:- not all sails shown for clarity

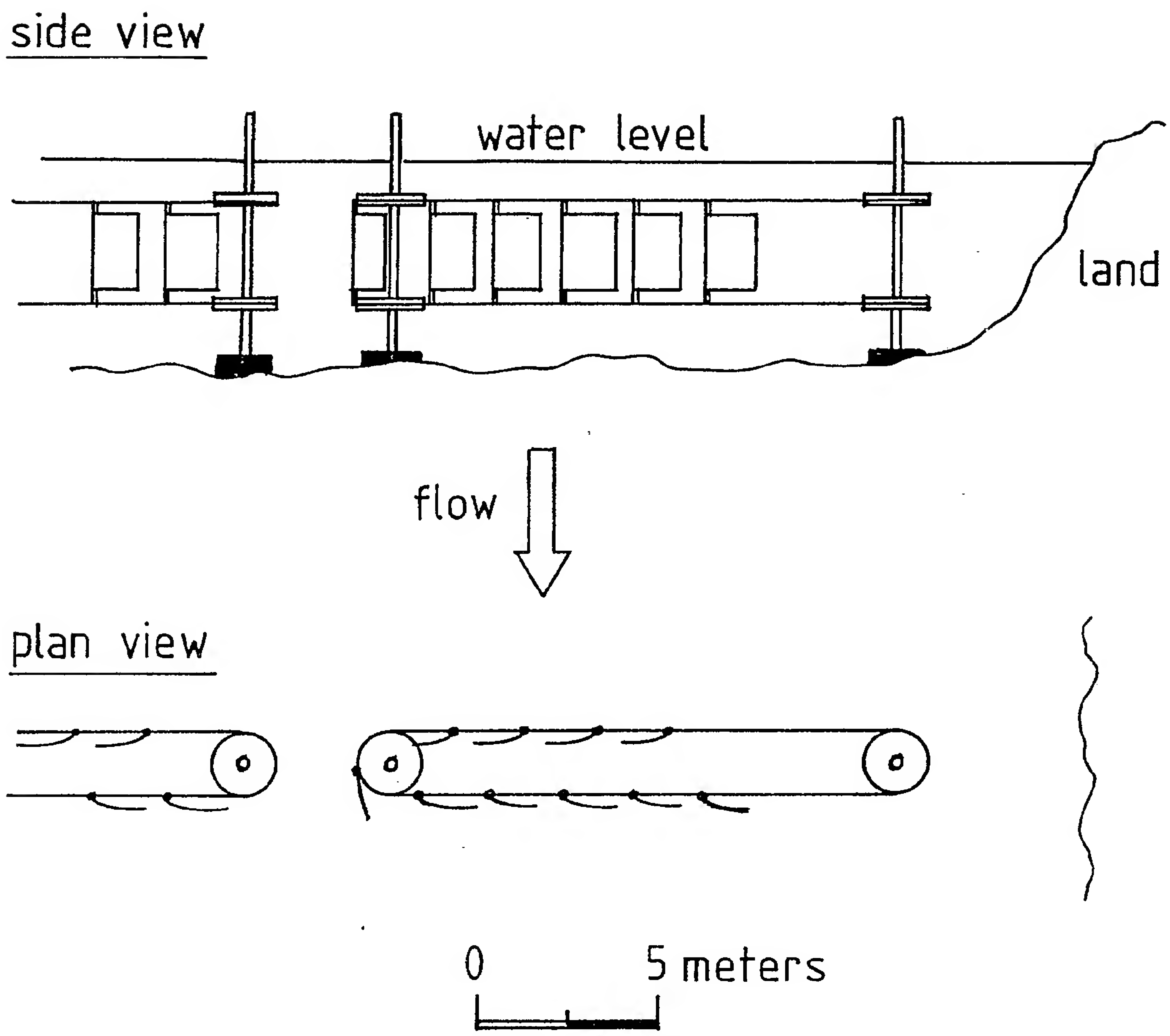
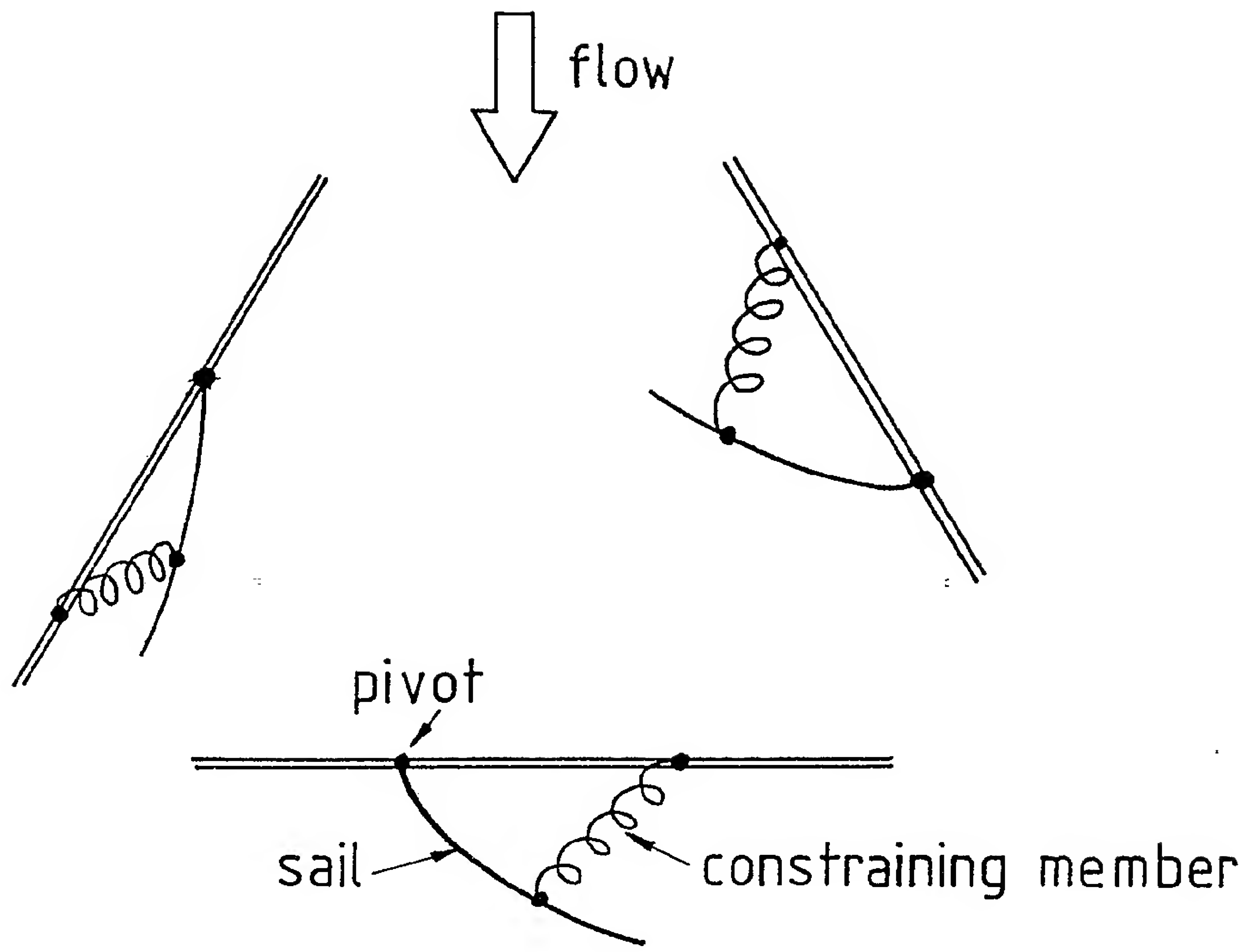
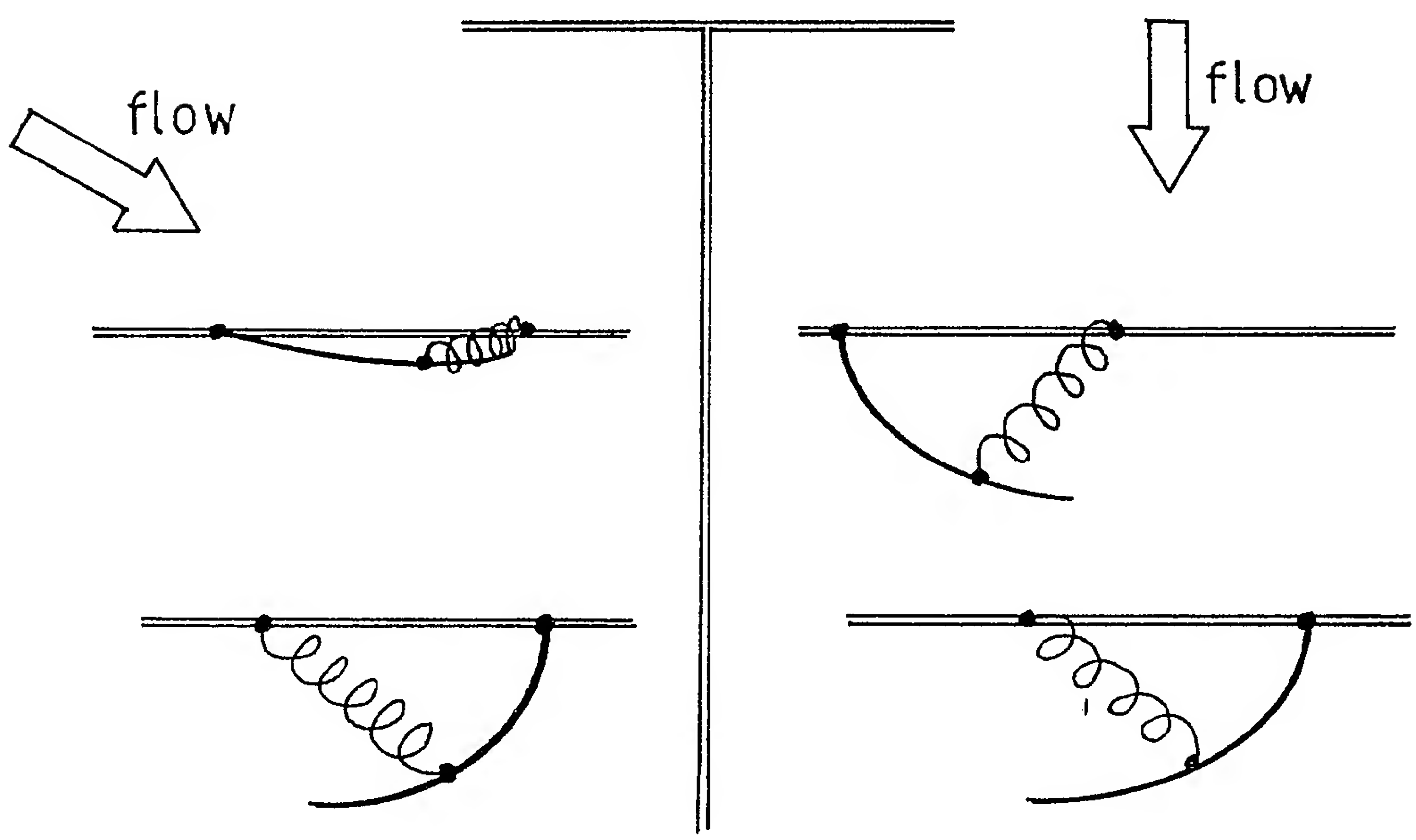


fig 1b



3 Mast System



2 Mast System

fig 2

2131490

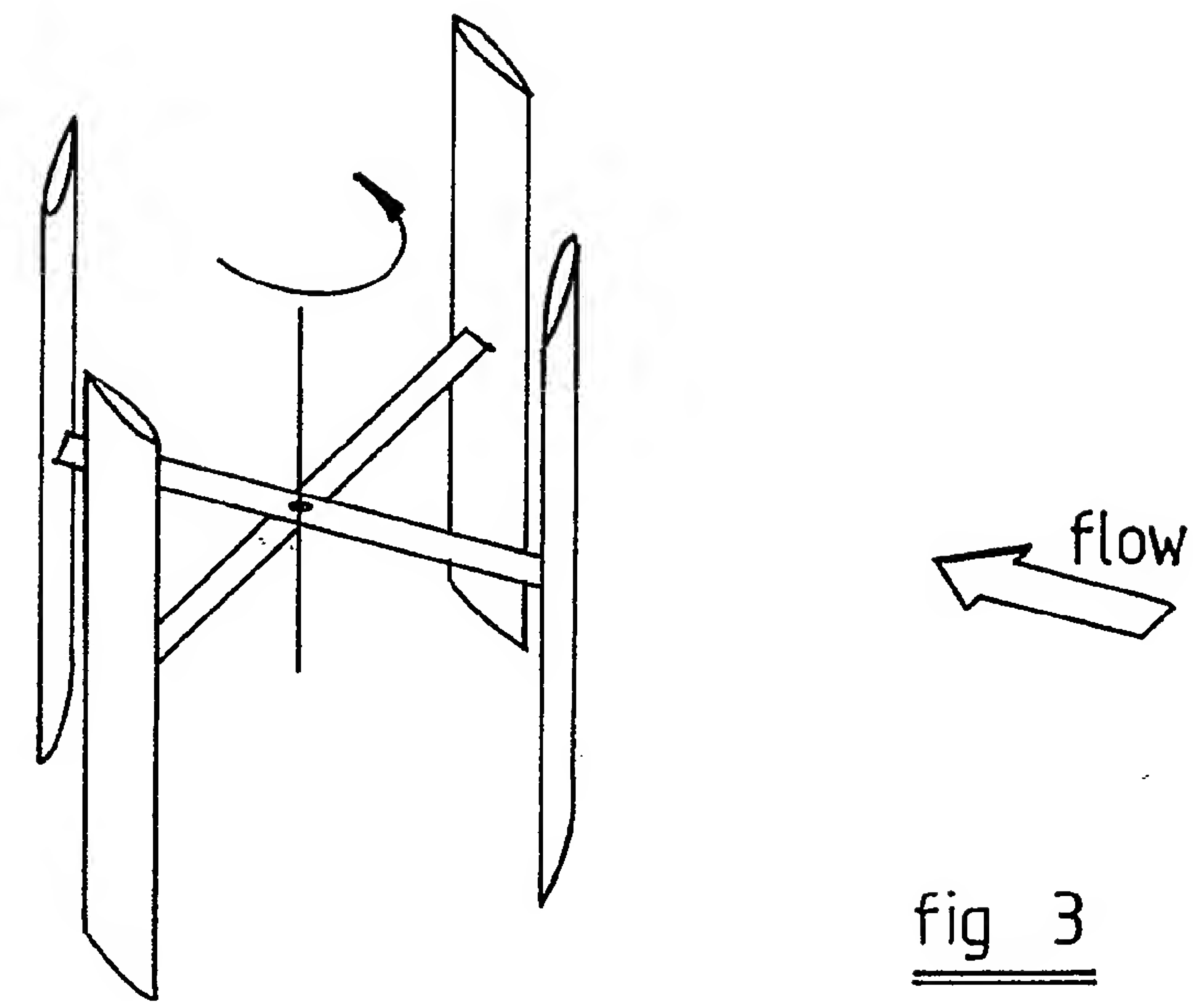


fig 3

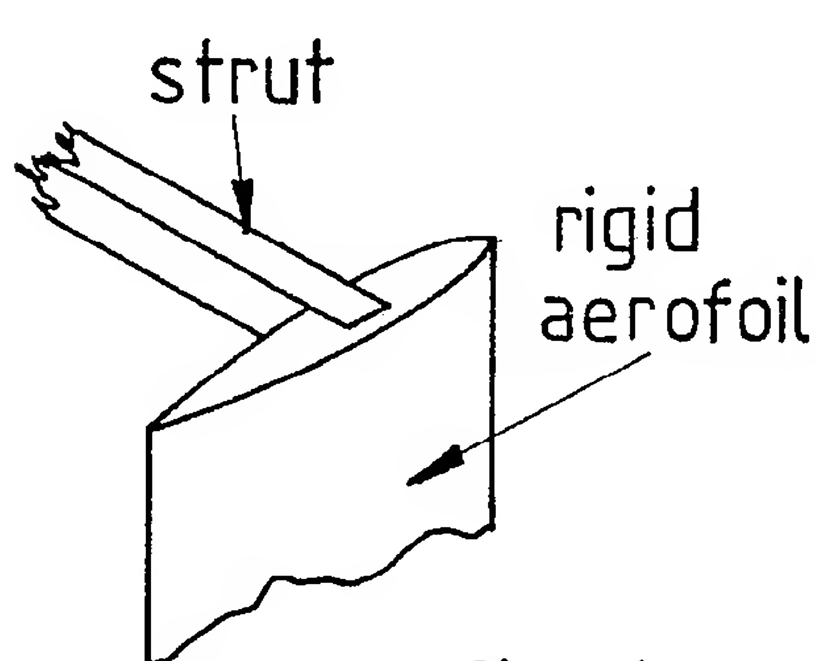


fig 4a

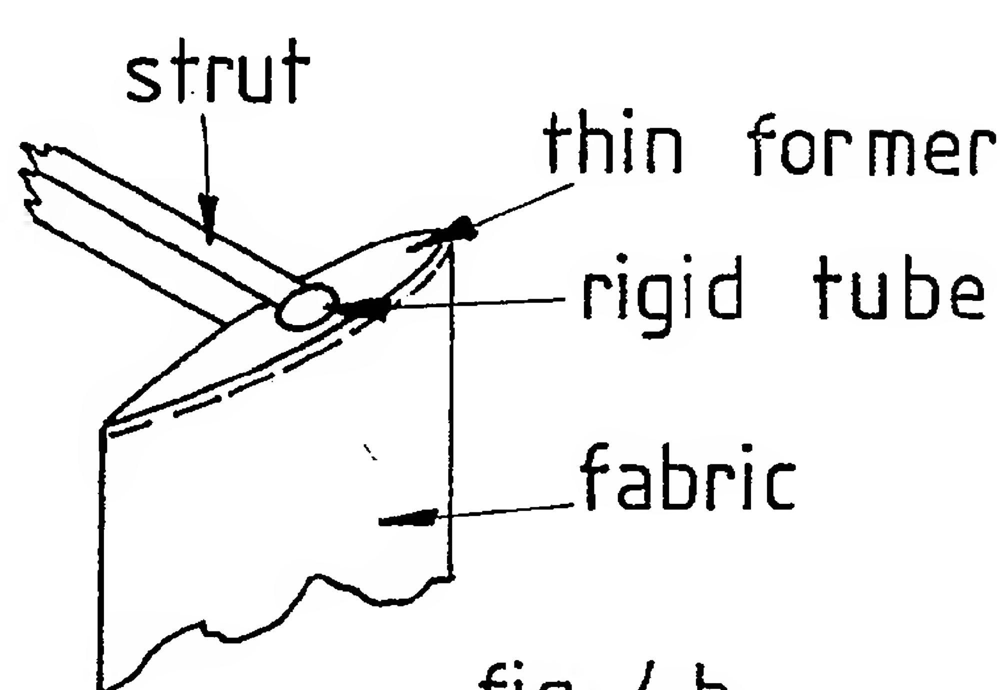


fig 4b

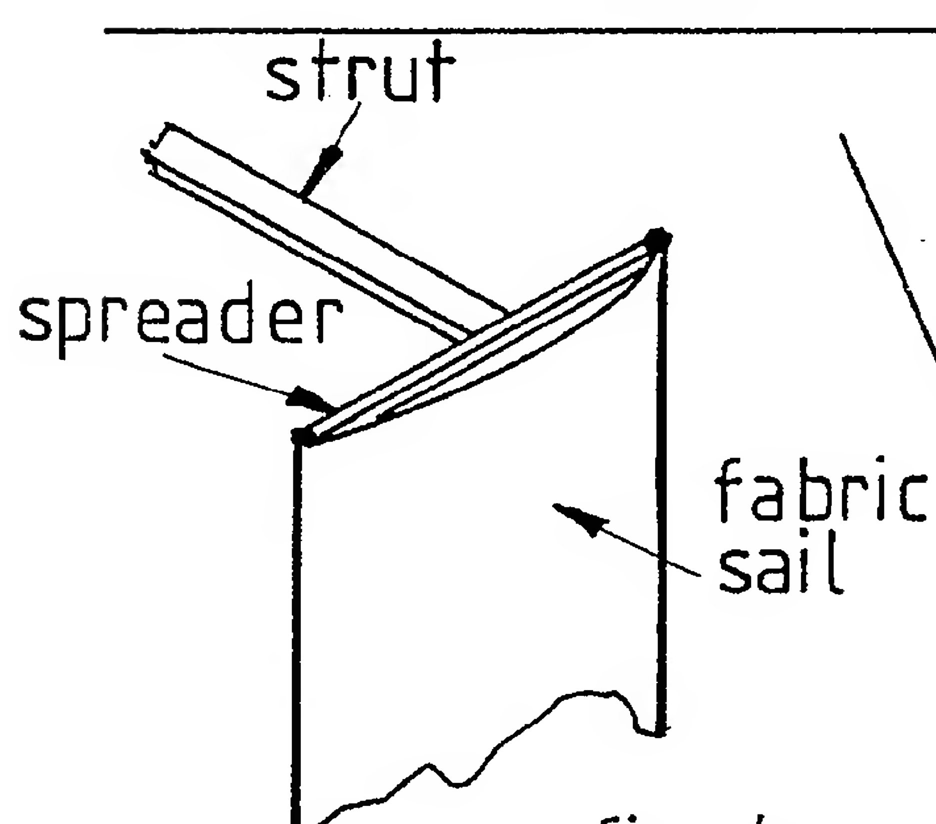


fig 4c

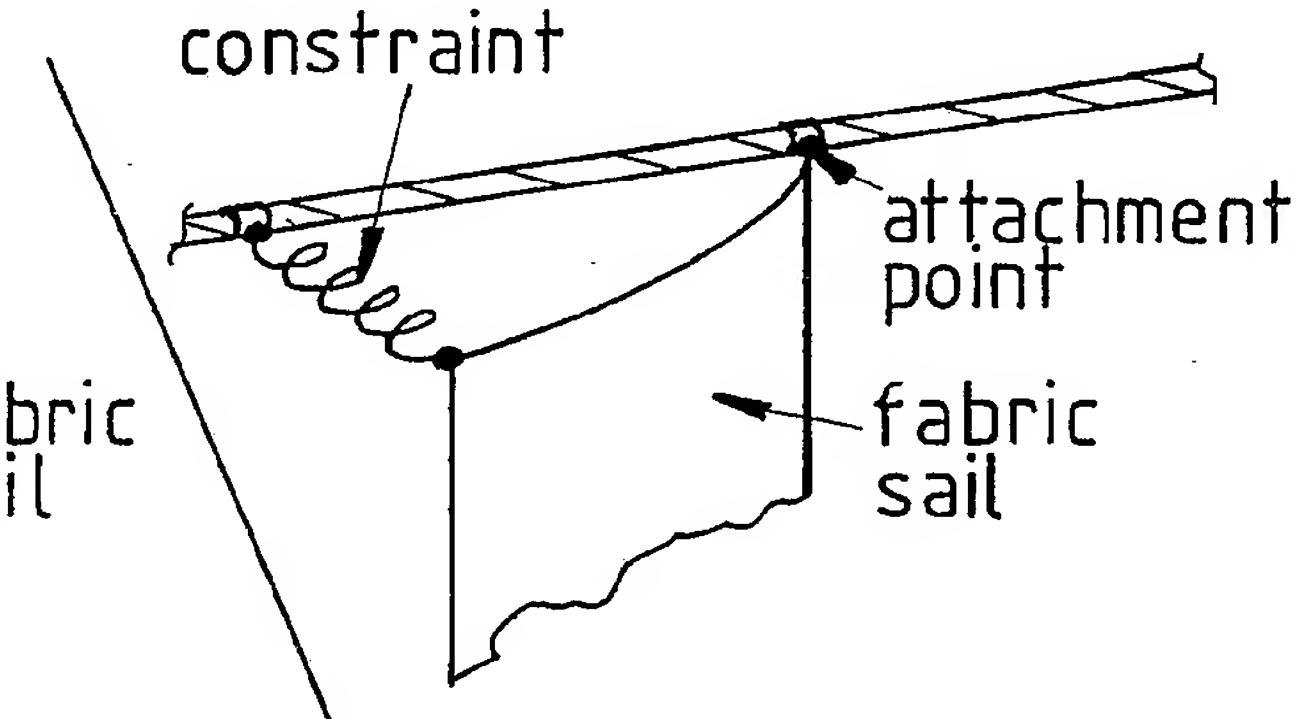


fig 4d

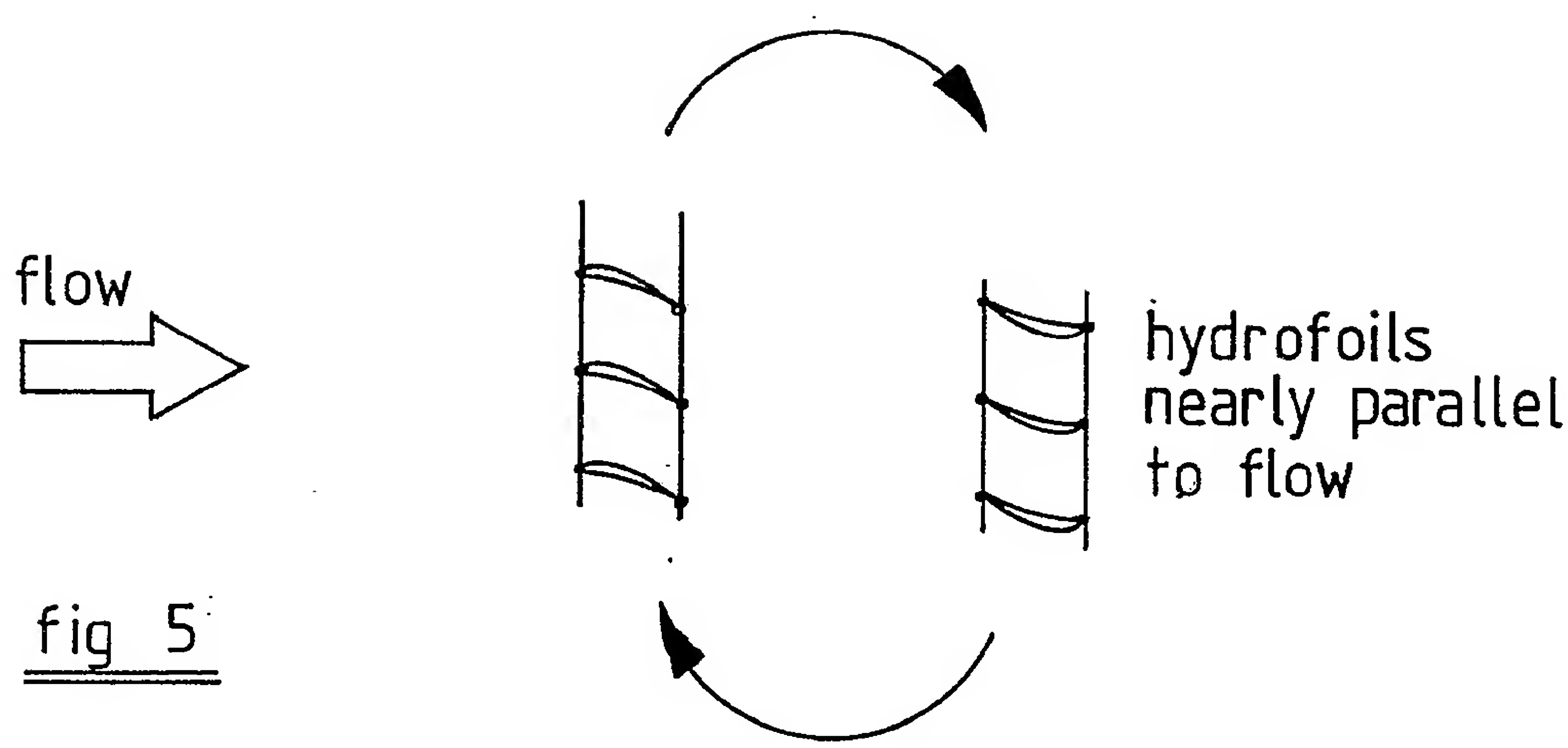


fig 5

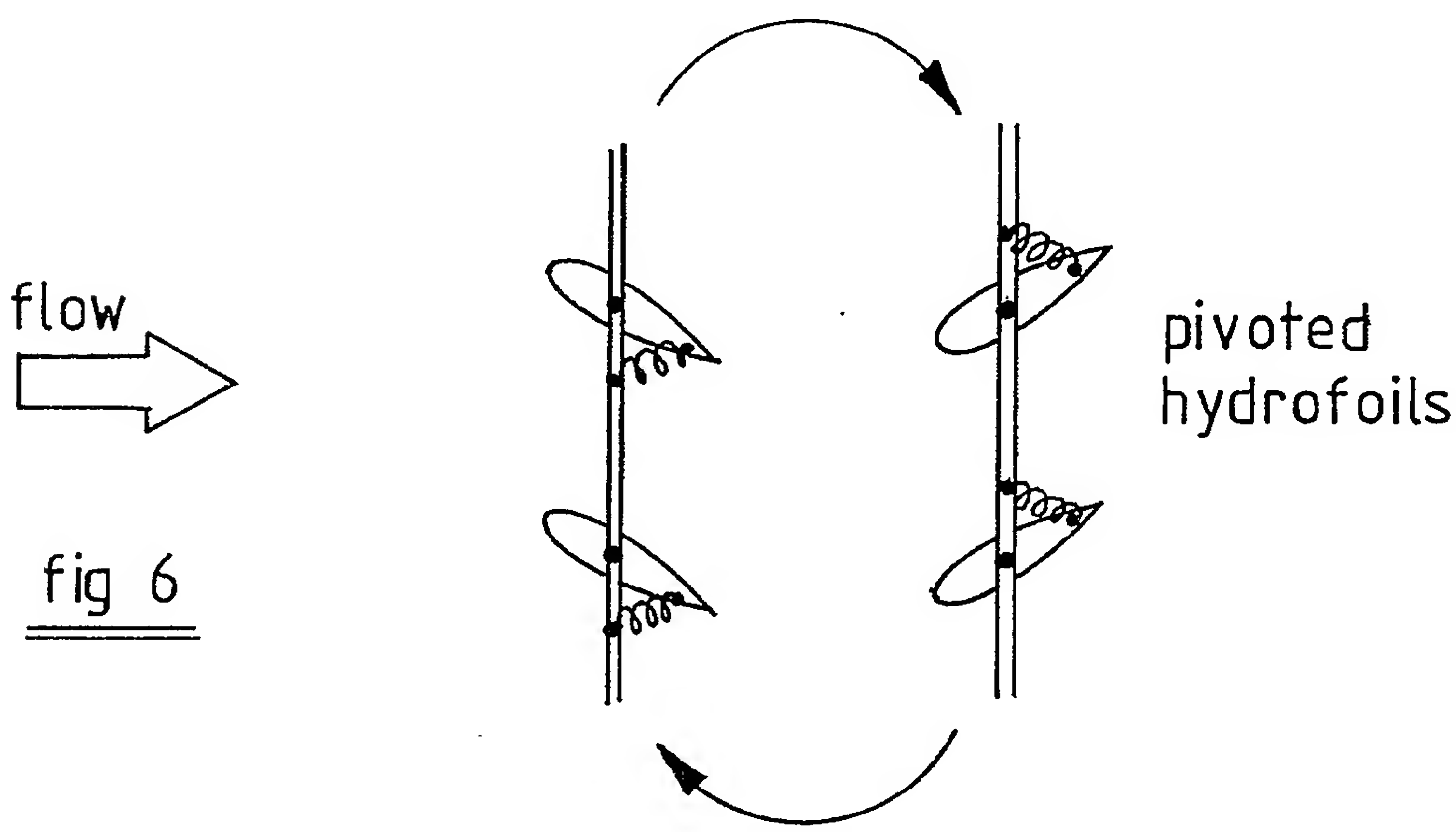


fig 6

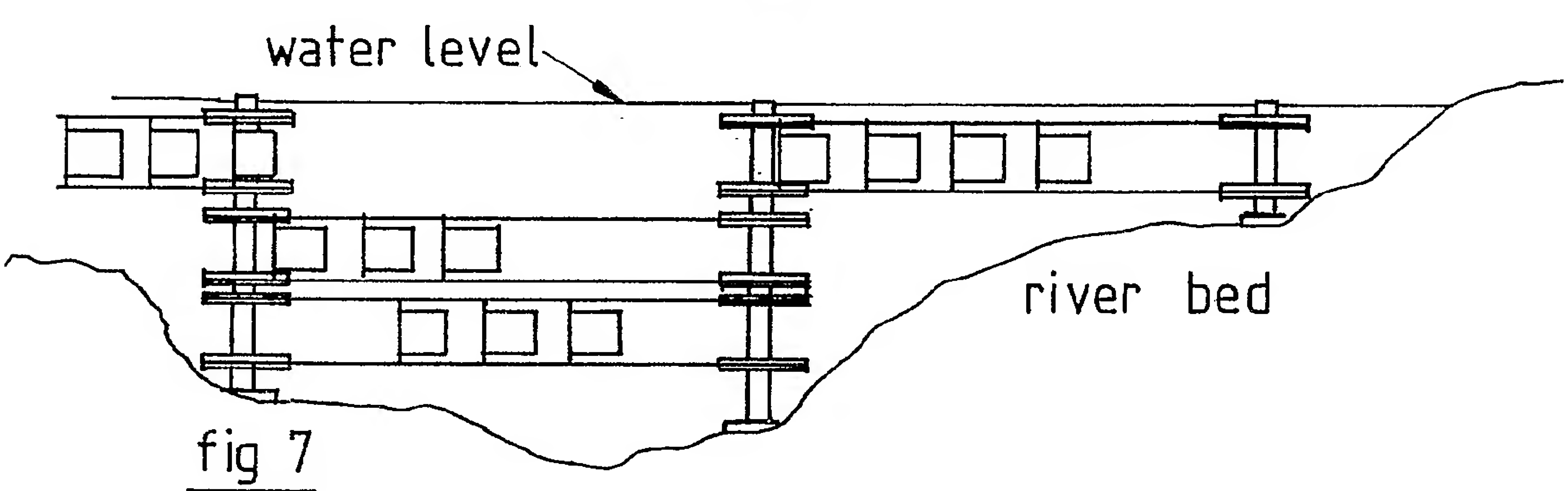
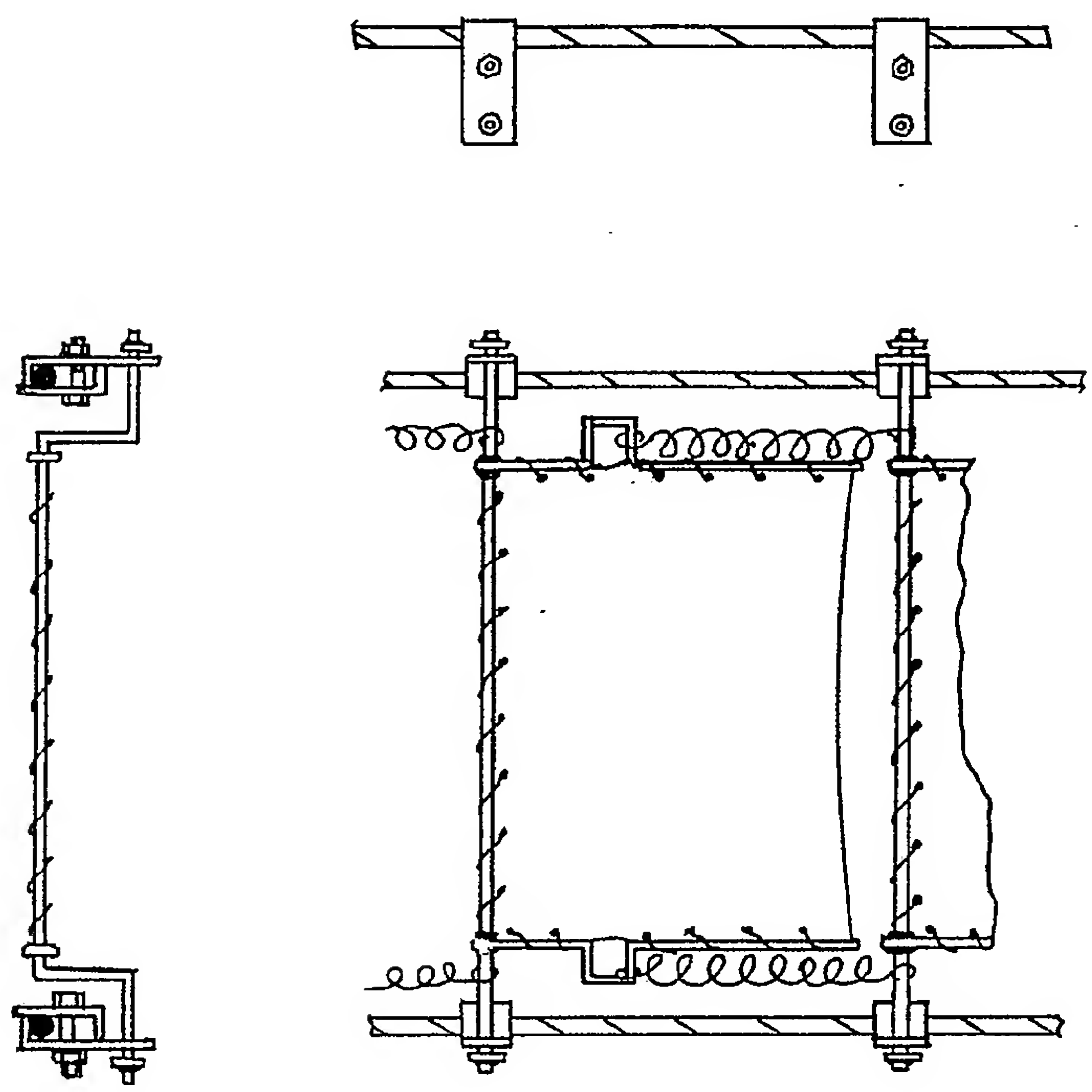


fig 7

third angle projection



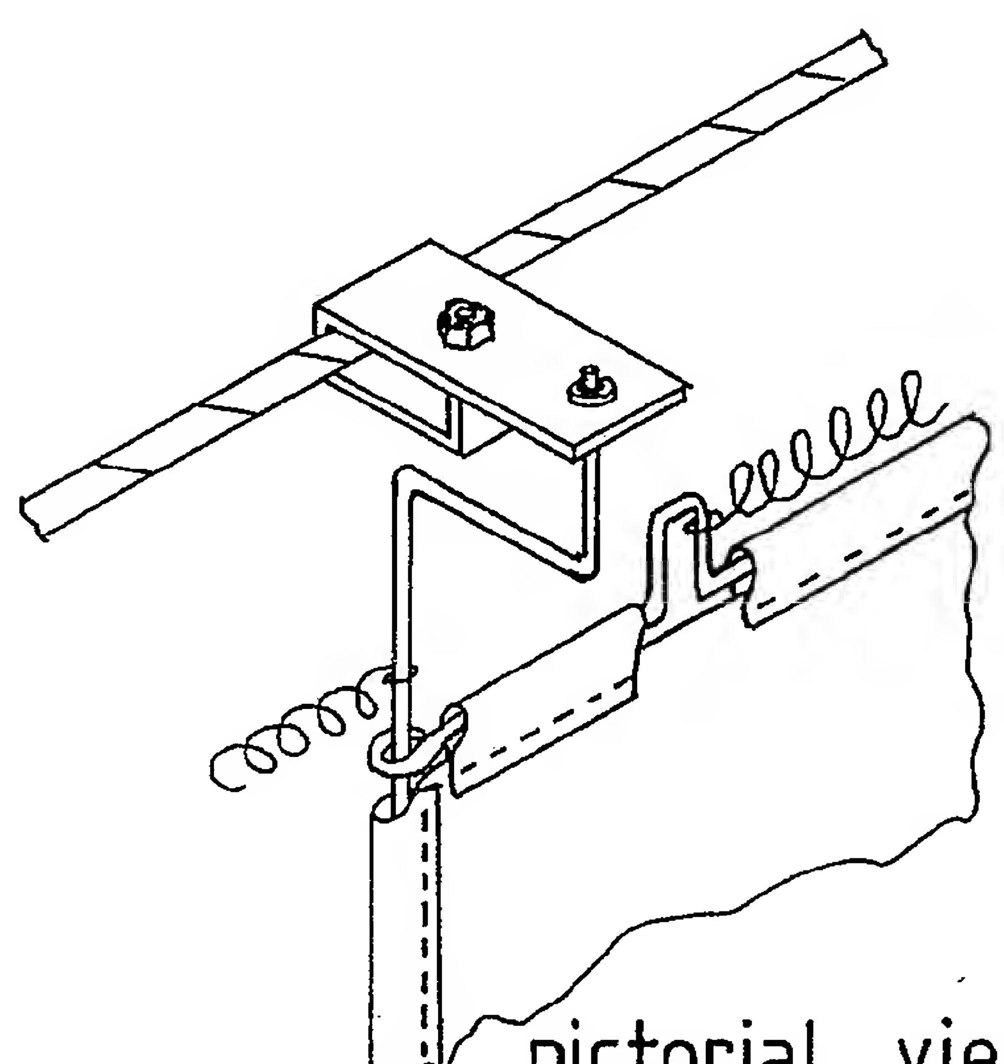


fig 8

pictorial view

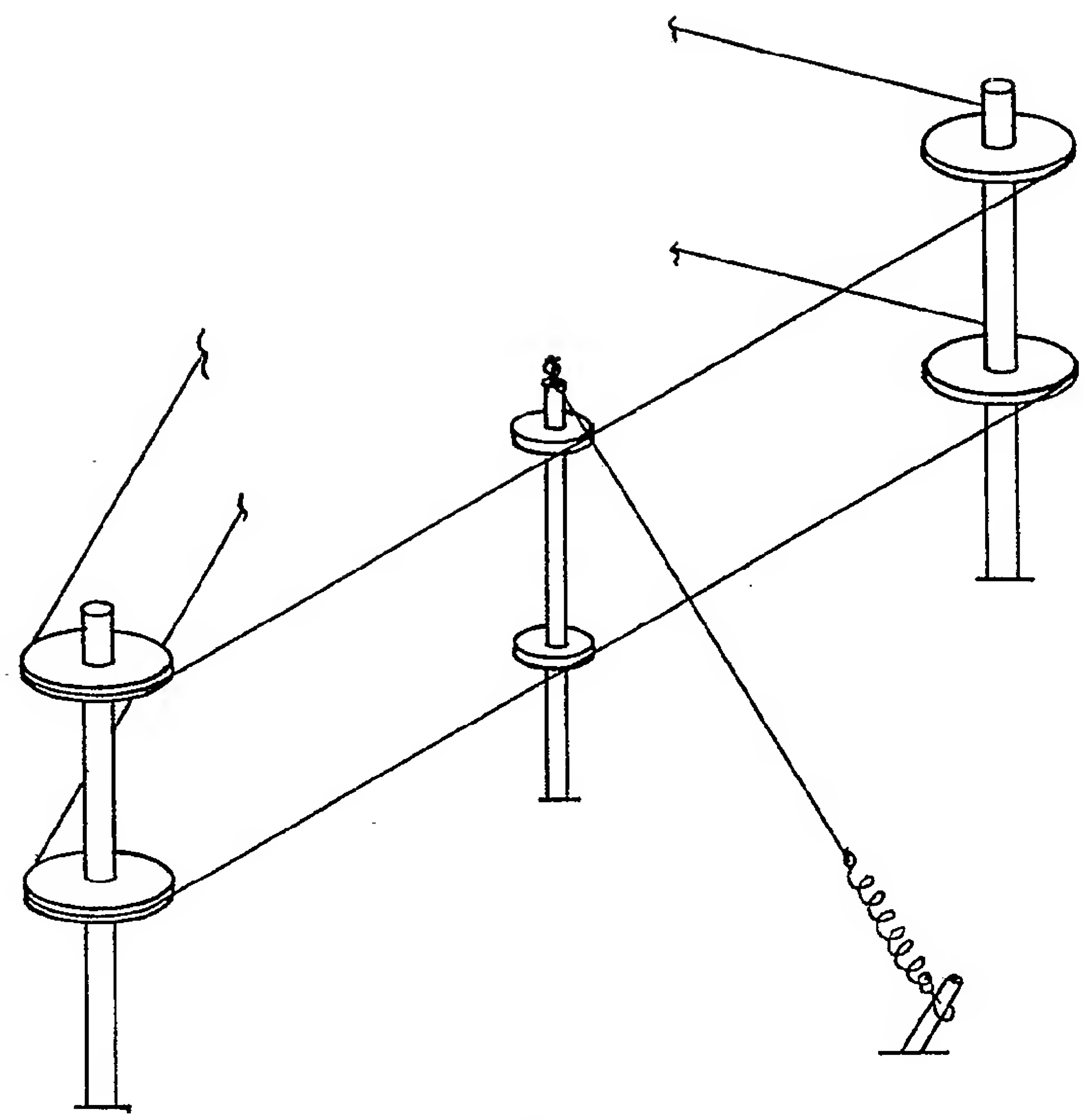


fig 9

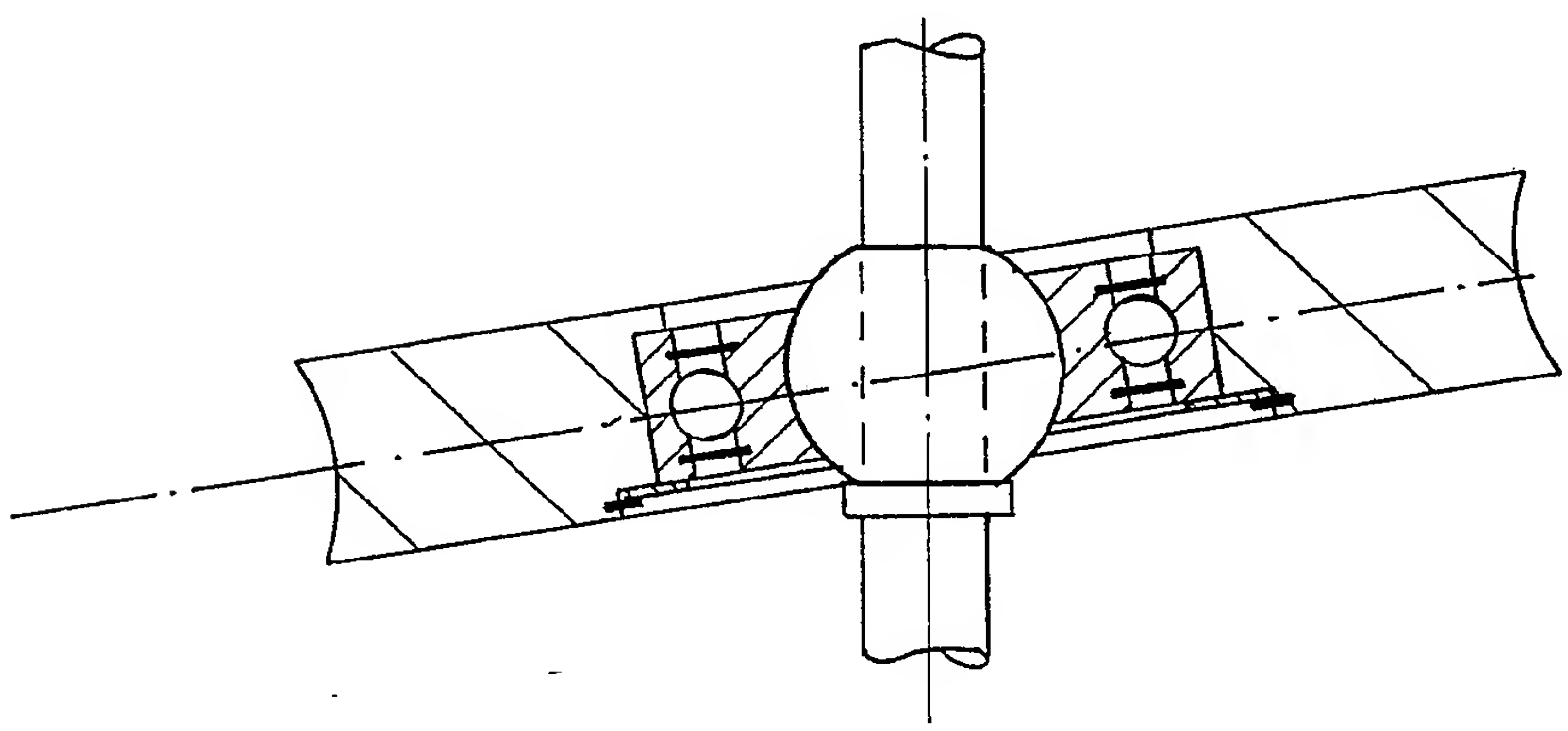
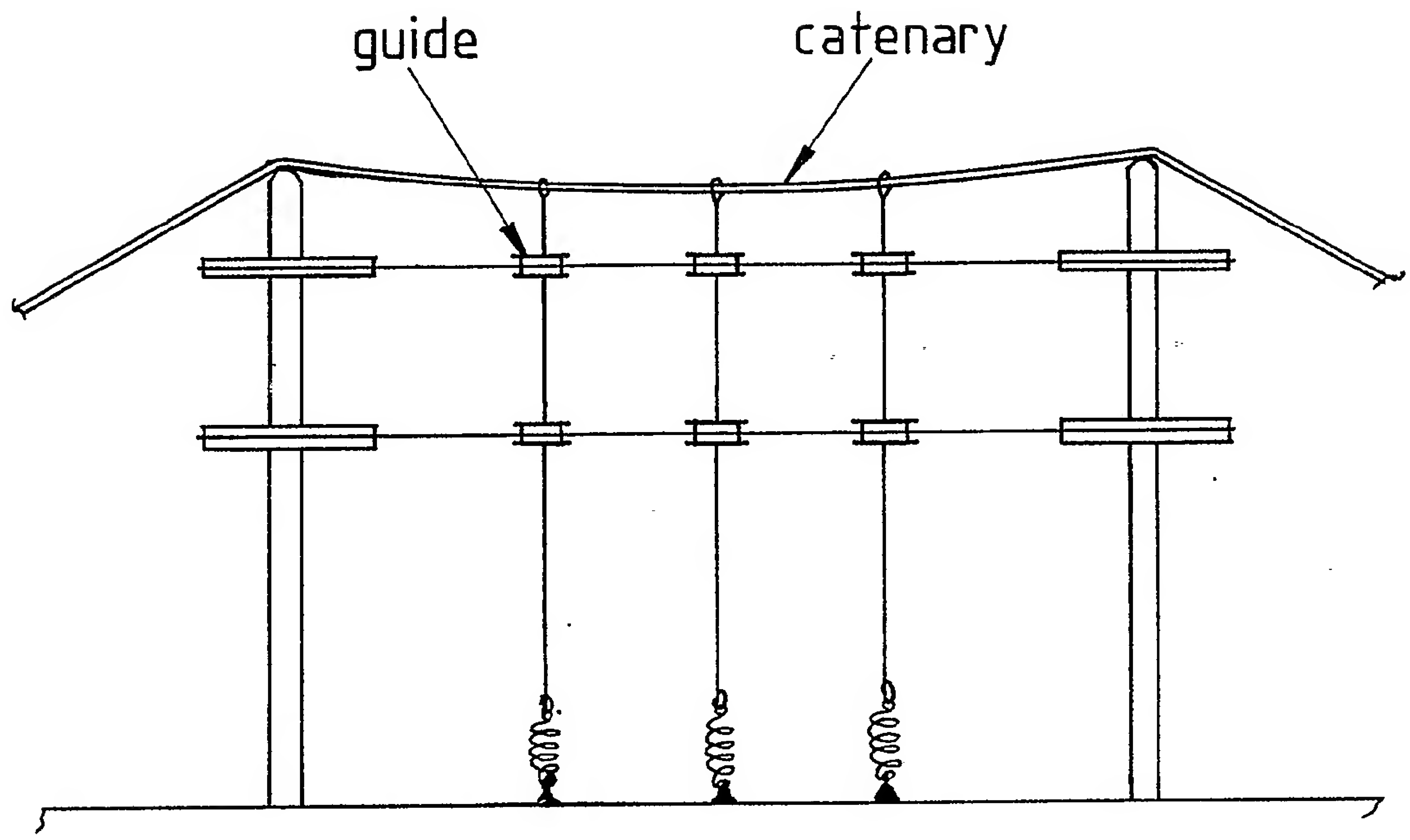


fig 11


guide
catenary

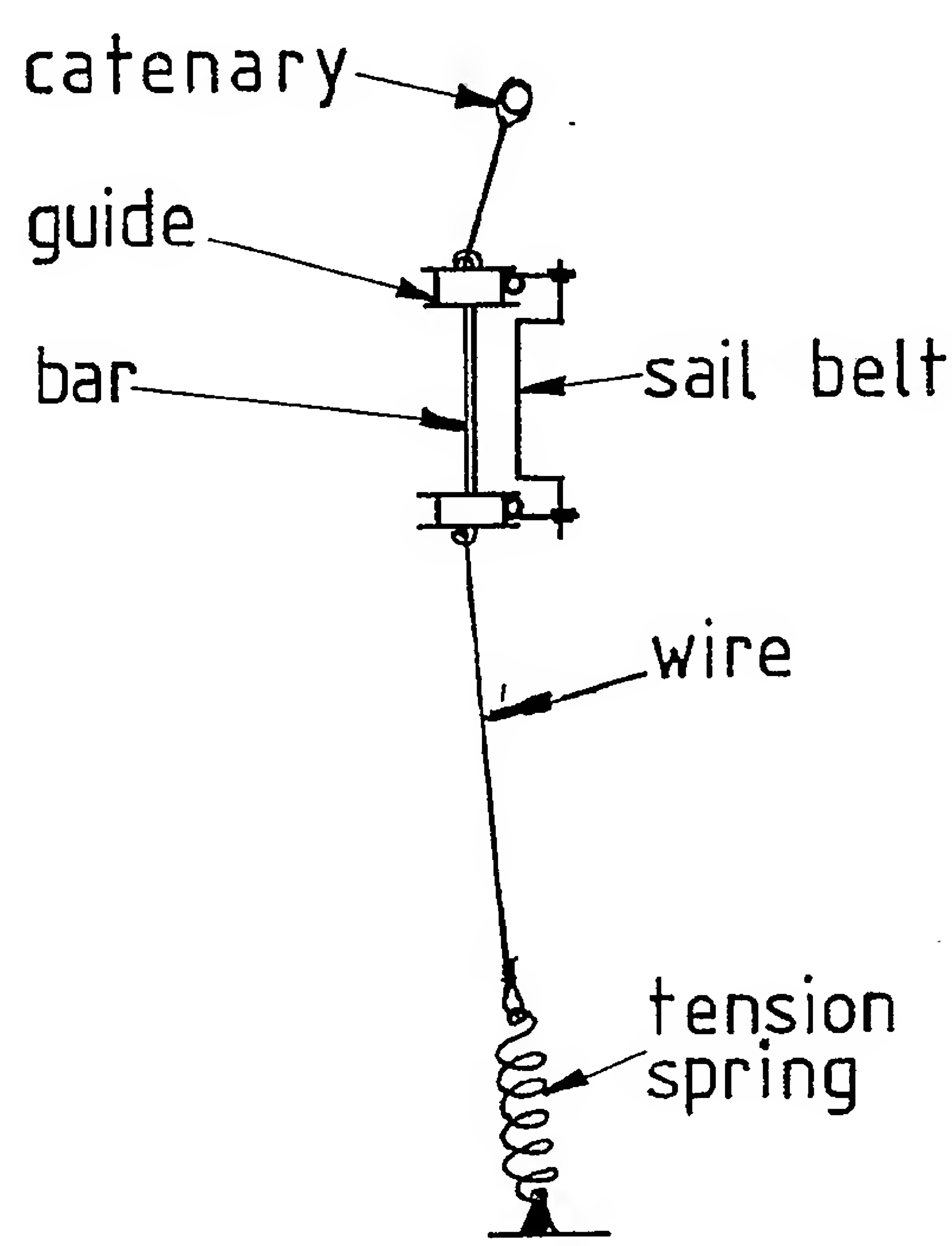

catenary
guide
bar
sail belt
wire
tension spring

fig 10

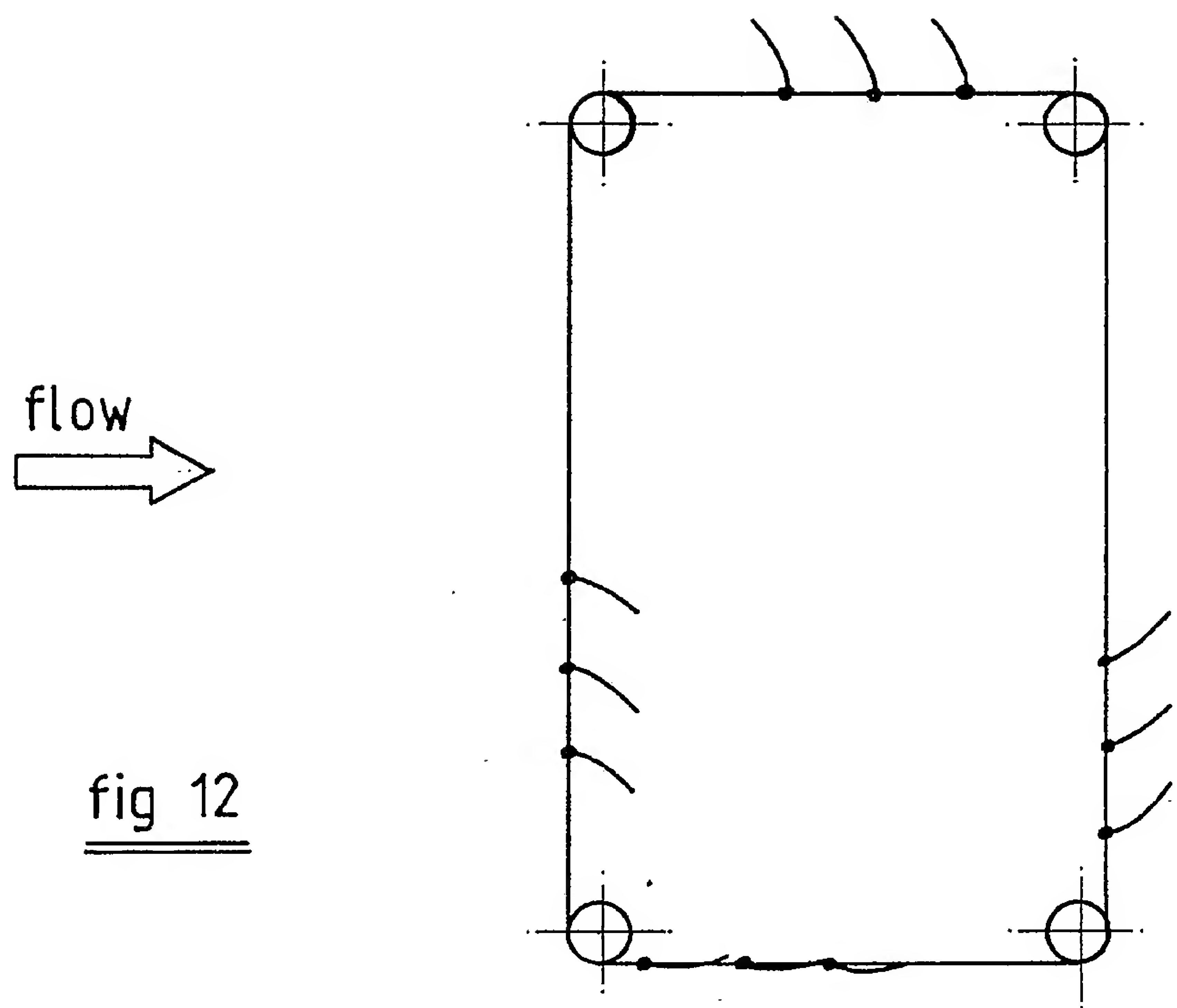


fig 12

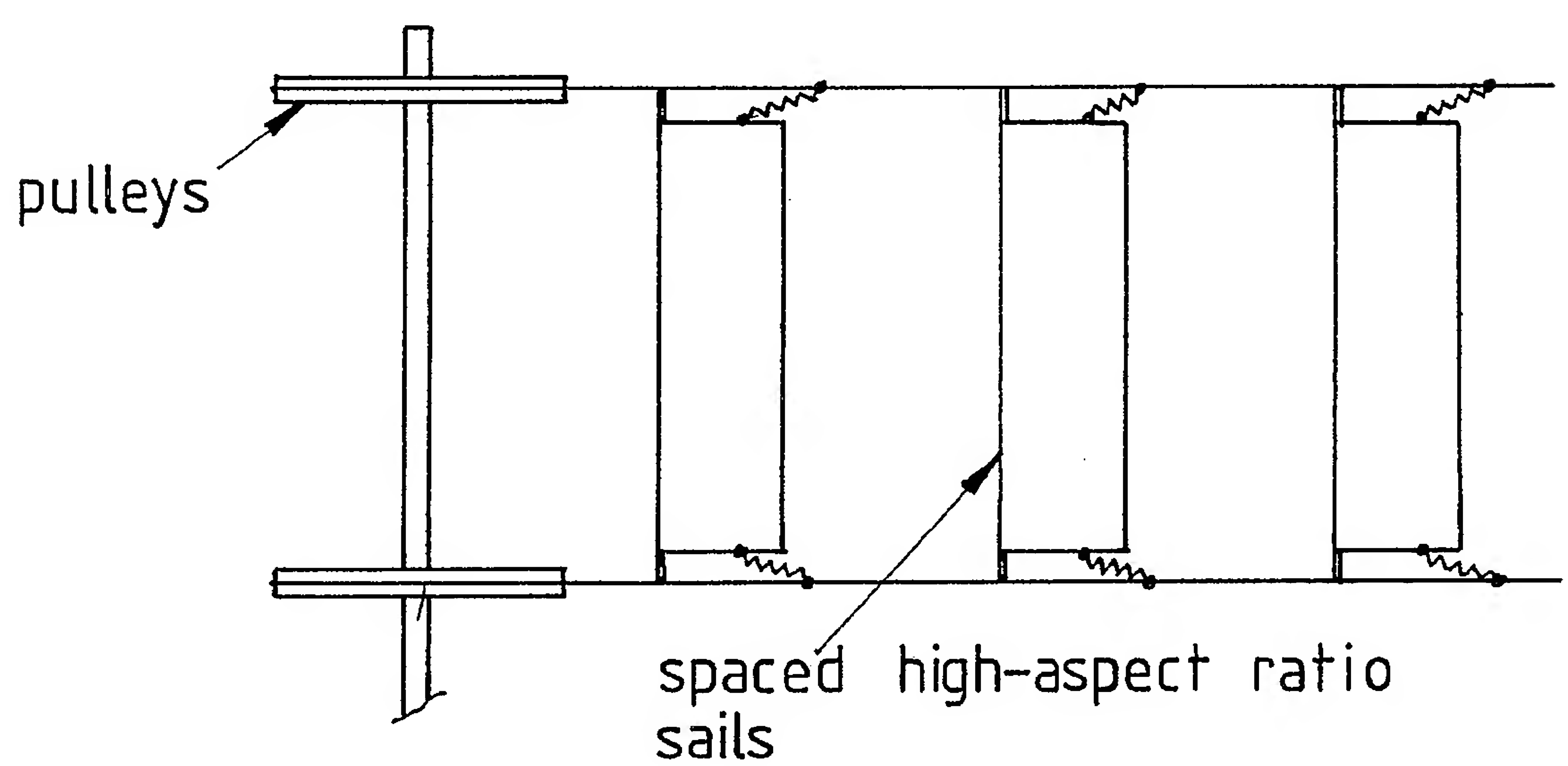


fig 13

SPECIFICATION

Device for extracting energy from flowing water or wind

Technical field

Devices for extracting energy from the flow of water or the wind; watermills or windmills; water or wind turbines.

Background art

Naturally flowing waters—rivers, tidal streams and sea currents—can contain large amounts of energy, but in comparison to more conventional energy sources, their energy densities are quite low. This is also true for flowing air in the form of the wind.

Many devices exist, or have been proposed, to extract this energy. To do so economically, despite the low energy densities involved, such devices must therefore be low in cost per effective unit of cross-sectional area they offer to the flow. This is seen as a primary characteristic of the device described herein.

Disclosure of invention

This invention consists of placing a series of sails along a pair of parallel endless belts. The belts run around two or more fixed pivot points that are placed some distance apart, and the force of the fluid on the sails causes the belts to move. Energy can be extracted from either the linear motion of the belts, or the rotary motion at one or more of the pivot points.

The features that distinguish this invention from similar ones are as follows:

1. The sails are not rigid aerofoils or hydrofoils, but are essentially flexible members of little thickness. Typically they would be made of cloth or plastic sheet, possibly of thin flexible metal sheet.

2. The sails are attached to the endless belts at points that are substantially near the leading edge of the sail Constraining members are connected between points on the sails, closer to the trailing edges, and the endless belts.

3. In usual applications the axes of the motion of the belts around the pivot points will be vertical, or nearly so. The orientation and shape of the sails is such that during at least a portion of their motion the fluid produces forces of lift upon the sails, and not solely forces of drag.

4. In some applications the pair of endless belts may be replaced by a single endless belt.

A sketch of the invention when used in the form of a wind energy extraction device is shown in Figure 1a. The number of pivot points about which the belts run depends on the application; where the wind blow strongly from one quarter only, two pivots may be adequate, where the wind blows from a variety of quarters three or more pivot points may be required.

Figure 1b shows the invention when used to extract energy from a flow of water. In this application two pivot points would be usual. In both Figures 1a and 1b dimensions are given for illustrative purposes only.

Figure 2 depicts the general principle of the fixing between the sails and the endless belts, and illustrates sail response angles for different configurations. The motion of the water or air past the sails transmits a forward motion to the belts in the same manner as on a fore-and-aft rigged sailing vessel.

The constraining member to be used with the sails may be either rigid (such as a metal rod), flexible but inextensible (such as a wire rope), or flexible and extensible (such as a wire spring or elastic cord). An example of the latter is illustrated in Figure 8, which shows one of the many attachment configurations possible. An advantage of a flexible, extensible constraining member is that transient loads can be evened out, and that a measure of protection is afforded in high fluid flow conditions, where the sails move to positions more nearly parallel to the fluid flow and the resultant force on the belt tends to a limit. Note that the illustrations depict constaining members that act in a passive mode. This invention includes the use of active constraining members that can alter sail position in response to some mechanism, either for the purpose of improving the device's performance or to prevent the device from overloading at high wind or water velcoties.

The main advantages of this invention

A main advantage of this invention stems from the use of the endless belt. This allows a multiplicity of aerodynamic or hydraulic active surfaces to present a large cross-section to the fluid flow while itself contributing relatively little to the device's support or structure cost. This is because much of the device uses members in tension, and these therefore have a lower cost than devices where components are in compression, or compression and tension.

A second advantage is that by using flexible sails as the active surfaces their cost may be lower than the more rigid surfaces used in conventional designs.

A third advantage is the constructional and operating simplicity of this device. Additional advantages are discussed below.

Comparison to prior art

Because of the somewhat different nature of the prior art in the cases of energy extraction from water and air flows, the two cases will be discussed separately.

A. Energy extraction from flowing water

For extracting energy from flowing water it has been usual to concentrate the flow at one or a few points by the use of a stationary structure such as a dam, weir or barrage. Despite the simplicity of this structure, it can represent a massive capital cost, especially in the case of tidal or sea current schemes. This is evidenced by two major tidal schemes now under consideration: the Severn barrage in the U.K., and the Bay of Fundy scheme

in Canada. In both cases, despite reasonable projections on the long-term cost of power envisaged, the high initial capital costs pose severe impendiments to implementation.

The invention described herein, by virtue of its low capital cost per unit of cross-sectional area offered to the flow, can provide a desirable alternative technique for energy extraction in such applications. In addition, the capital cost of a project may be further reduced with this device, by, in the first instance, intercepting only a portion of the total water flow.

It is likely that the invention described herein will have a lower efficiency in converting water flow energy to mechanical energy than present water turbines. This is because of the relatively low speed and poor profile of the active surfaces in this invention compared to conventional designs. Even so, it is possible that not only the capital cost but also the life-cycle cost of power produced by this invention may be lower than from conventional designs. This would be because the lower capital cost, and reduced financing charges incurred thereby, would more than offset the lower efficiency.

Other general advantages of this invention may include:

The ability to permit the free passage of water vessels by placing the top of the active surfaces somewhat below the water surface.

The ability to be more suitable for those areas of the world where local materials such as rope, jute and woven goods are considerably less expensive than manufactured materials and metal or concrete structures.

Comparison to specific prior art (Water flow)

a. Conventional water mills and water turbines. Comparison with these devices has been dealt with above.

b. Vertical-axis water turbine using hydrofoils as illustrated in Figure 3 and Figure 4(a). The invention described herein offers a much larger cross-section to the water flow. Additionally, the active surfaces are flexible sails rather than rigid hydrofoils and hence may be less costly.

c. Devices where the active surfaces extract energy from the flow by moving for a time in the direction of the flow, and being in some manner feathered or removed from the water when being returned to the starting point. (For example U.K. Patent 1,504,104, or Popular Science Magazine December 1981 p. 34). Such devices require structure or mechanism to be built in the direction of the flow, and hence are costly when intercepting large cross-sections of the flow. Secondly, it is well known that such devices are generally less efficient (being devices acted upon by drag forces only) than devices that are acted upon by lift as well as drag forces, such as sails or hydrofoils.

d. Devices where an endless belt of hydrofoils move perpendicular to the flow, but the chord of the hydrofoils are nearly parallel to the flow, as illustrated in Figure 5. (For example U.K. Patents 403,607 or 188,728 or 1,515,894). Such devices are generally less efficient than devices that move with their active surfaces more nearly perpendicular to the flow. This is compounded by the fact that the downstream hydrofoils are oriented with the rear of their chord to the flow. As a result the flow across the downstream hydrofoil is difficult to optimize and depends on proximity to the upstream hydrofoil. Often stationary blades between the upstream and downstream belts are suggested to reduce this problem but this adds to the cost. Mechanisms have been devised for reversing the orientation of the downstream hydrofoils but this also adds to the cost. By contrast, in the device described herein, the sails change orientation from one side of the belt to the other automatically under the pressure of the water flow as the belt varies from being on the upstream or downstream side of the device. A second distinguishing feature of the invention described herein is that the active surfaces are flexible sails, rather than rigid blades or rigid hydrofoils. Sails are likely to be less expensive.

e. Endless belt devices where the active surfaces are rigid blades (i.e. thick or thin members without the flexibility of sails, that are pivoted at points on the endless belts and are fitted with a constraining member joining the blade to the endless belt, as in Figure 6. See for example U.K. Patent 629,798). The hydraulic performance of rigid blades is likely to be poorer than the flexible sails of the invention described herein, and their cost and weight will be higher than flexible sails.

B. Energy extraction from the wind

For extracting energy from the wind the conventional design of windmill has its full cross-sectional area swept by a single rotating element, with this supported on a tower or similar structure.

This configuration has two disadvantages. Firstly, the cost of the tower is often a major portion of the total installed cost. This is in contrast to the invention described herein where, though two or even more tower structures are required, the effective cross-sectional area of the active surfaces is great, so that the tower cost per unit of energy intercepted is low.

Secondly, as conventional windmills increase in size, they start to incur major problems in terms of the rotating loads that have to be borne by the members, and by associated problems of vibration. This is in contrast to the invention described herein, where a large cross-sectional area, and hence large power output is achieved with only relatively slow velocities of the moving elements.

It is likely that the invention described herein will have an efficiency in converting energy in the wind to mechanical energy that is lower than the better performance horizontal and vertical axis wind turbines currently available. This is because of low speed and poor profile of the active surfaces when compared to high performance

current designs. Even so, on balance it is to be expected that in many curcumstances the life-cycle cost of power produced by this invention will be cheaper than that from conventional designs because of the reduced cost in tower and rapidly rotating elements, and reduced cost of using sails to replace solid aerofoils.

Other general advantages of this invention may include:

The ability to be more suitable for those areas of the world where local materials such as rope, jute and woven goods are considerably less expensive than manufactured materials.

Comparison to specific prior art (wind)

a. Conventional windmills and wind turbines that use a single rotor (or a small number of rotors) supported on a single tower or structure. This includes horizontal axis and vertical axis aerofoil designs and Savonius and Darrius designs. Comparison with these devices has been dealt with above. Note that general lists of windpower devices given in modern textbooks do not include the invention described herein. (See for example "Wind machines", F. R. Eldridge, Mitre Corporation, 2nd edition, 1980; and "Windpower: A Handbook of Wind Energy Conversion Systems", V. D. Hunt, Van Nostrand, 1981).

b. Devices that use thin flexible material in the construction of lightweight but essentially fixed aerofoils. Fabric may be used to enclose a volume, as in the true sailwing design of Figure 4(b), or form a thin aerofoil as in Figure 4(c). Both these cases should be contrasted with the sail of the invention described herein, Figure 4(c), whose trailing edge has considerable allowable movement and so is suitable for the change in direction of travel when attached to an endless belt. Active surfaces of the types shown in Figures 4(b) and (c) have generally only been suggested for single-rotating-element conventional windmills, with the exception of the endless belt windmill depicted in Popular Science Magazine February 1982 page 85. The advantage of sails described in this invention is that they are effective at relatively low wind speed/tip speed ratios, and this is the regime in which an endless belt device inherently operates. The essentially fixed aerofoils/hydrofoils of Figures 4(b) and (c) only operate at high efficiencies at high tip-speed ratios.

c. Devices that are essentially endless belt devices, but using trackways built upon the ground on which trollies run. (For example U.K. Patent 1,168,314). Such devices will always be prohibitively expensive in track and trolley cost.

Embodiments

Figures 1a and 1b show possible configurations of this invention, with dimensions given for illustrative purposes only.

The endless belt may be made of rope of natural fibre, or plastic rope (e.g. polypropylene), or wire rope or a chain. The sails might be made of cloth, woven plastic or thin plastic or metal sheet. The constraining member may be fixed, such as a wire, or elastic such as a spring or elastic rope. A wide range of designs and fixings of the constraining members are possible and are not restricted in this invention, save only that they must perform their duty of holding the sails in an appropriate position when the belt is on both the upstream and downstream part of its travel. The power take-off might be by geared or friction wheel on the belt, by rotary motion at the pivot points or by other electrical, hydraulic or mechanical means.

Figure 7 shows how multiple towers (with possibly a single power take-off point from each tower) can be used as the geometry of sails and belts require.

Figure 8 shows one embodiment of the sail structure for a high-solidity design.

Figures 9 and 10 show possible structures that may be needed to control sag and flutter when extracting energy from the wind. When extracting energy from water flow, somewhat similar structures may be needed to offset the high drag forces encountered. Figure 11 shows angled wheels that may improve belt travel at the pivot points. Figure 12 illustrates that even when the fluid flow is predominanly from one direction that 4 or more pivot points may be used to reduce the effect of the upstream sails on those downstream.

Figure 13 illustrates that a low-solidity device (significant spacing between the sails) may improve performance, reduce cost or achieve both.

Claims (Filed on 25.7.83)

1. A device for extracting power from the wind or a flow of water that comprises:

(a) a plurality of sails attached to one or more endless belts that themselves run around two or more fixed pivot points;

(b) power is extracted from the motion of the belt or belts, or from the rotary motion at one or more of the pivot points; and characterized in that:

(c) the sails are substantially flexible and that

(d) the endless belt or belts are lightweight members in tension, and that

(e) the contact between the endless belt or belts and any fixed reference points such as footings in the ground, or the bed of the water channel, or devices anchored in the water channel, is substantially via the axes at the pivot points (or via occasional belt-guiding structures); not via fixed trackways or similar structures.

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